Airspace Systems Program: Relevance to Environment

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Outline

- Overview of NextGen-Airportal and Airspace Projects
- Airportal Project Research and Development
  - Surface Operations
  - Runway Management
  - Metroplex Operations
- Airspace Project Examples
  - Tailored Arrivals
  - Flight Deck Merging and Spacing
  - Energy Navigation
  - Closely Spaced Parallel Runways
  - San Francisco Stratus and Ground Delay
- Summary

Fundamental Goals

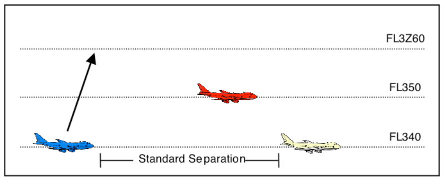
- End goal is to increase capacity, efficiency, and throughput
- Program products are directly related to environmental considerations
  - Reduced emissions are result of reduced delays
  - Reduced emissions are result of efficient routes

Airspace Systems Program

Revolutionary concepts, capabilities, and technologies to enable significant increases in the capacity, efficiency, and flexibility of the NAS

Oceanic In-Trail Procedures

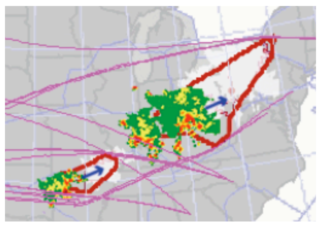
Enable efficient operations, altitude changes for favorable winds or turbulence avoidance, and climbs for optimal performance (less fuel burn)



blue = ADS-B transceiver and onboard decision support system
red = ADS-B out minimum required

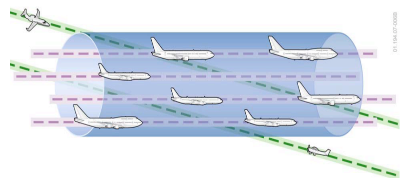
Traffic Flow Management

Allocate demand through departure times, route modification, adaptive speed control, etc., in the presence of uncertainty



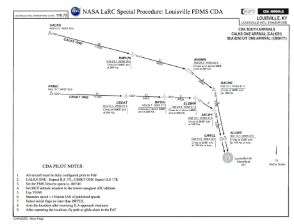
Dynamic Airspace Configuration

Increase capacity through dynamic allocation of airspace structure and controller resources



Merging and Spacing

Increase throughput on high-demand runways and reduce noise, fuel consumption, and emissions for arrival streams

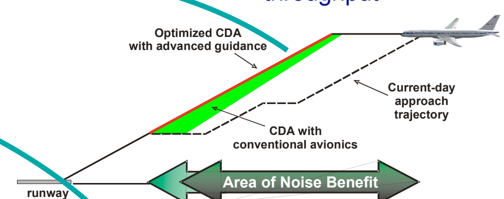


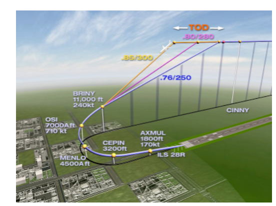
Trajectory Prediction, Synthesis & Uncertainty

Accurate trajectory predictions that are interoperable with aircraft FMS and trajectory generations using prediction uncertainly growth and propagation

Continuous Descent Approaches / Tailored Arrivals

Strategic, trajectory-based arrival clearances that allow a continuous descent at low engine power, maximize arrival throughput





Separation Assurance

Increase capacity and throughput by automatically detecting and resolving conflicts for transition airspace

Airspace Super Density Operations

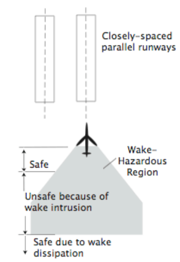
Increase capacity and throughput via simultaneous multi-objective sequencing, spacing, merging, and de-confliction for terminal airspace

Environmental Modeling

Identify, model, and integrate environmental constraints, as well as, mitigation options to be considered in the surface traffic optimization process

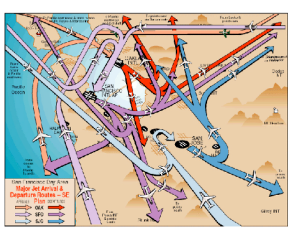
Very Closely Spaced Parallel Approaches

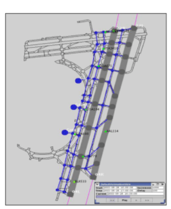
Stabilize capacity by enabling VMC arrival rates under IMC on runways as close as 750 ft., and substantially increase capacity by allowing construction of new runways between existing runways



Regional / Metroplex Airport Operations

Optimize integrated arrival / departure runway balancing operations





Today's System

- ~ 25,000 IFR flights per day[1]
- 70% of all delays > 15 minutes related to weather in last 5 years[1]
- 21% of all accidents from 1994-2003 were weather-related[2]

[1] FAA ASPM and OPSNET database
[2] NTSB Weather Related Accident Study, 2004

NextGen-Airportal Project
Research Focus Areas

Fundamental research purpose: investigate innovative new technologies, approaches, and procedures with the goal of enabling enhancements within the airport and terminal domains to meet NextGen capacity and efficiency goals

- ***Safe and Efficient Surface Operations***
  - Develop trajectory-based automation technologies to optimize ground operations
- ***Coordinated Arrival/Departure Operations Management***
  - Maximize throughput by means of increasing runway capacity and optimizing the *scheduling* of arrivals, departures and surface operations
- ***Airportal and Metroplex Integration***
  - Metroplex operations, system-level engineering and evaluations, and human-system integration

NextGen-Airspace Project
Research Focus Areas (continued)

Fundamental research purpose: increase capacity/throughput and address demand/capacity imbalance problem in the most safe, equitable, and efficient manner

- ***Capacity and throughput increasing elements***
  - ***Separation Assurance*** develops concepts and algorithms to automatically detect and resolve conflicts for transition and cruise airspace
  - ***Airspace Super Density Operations*** (simultaneous multi-objective sequencing, spacing, merging, and de-confliction) for complex terminal airspace (e.g. environmentally friendly with maximum throughput)
- ***Demand/capacity balancing elements***
  - ***Dynamic Airspace Configuration*** strives to increase capacity through dynamic allocation of airspace structure and controller resources
  - ***Traffic Flow Management*** works to effectively allocate demand through scheduling departure times, route modification, adaptive speed control, etc., in the presence of uncertainty

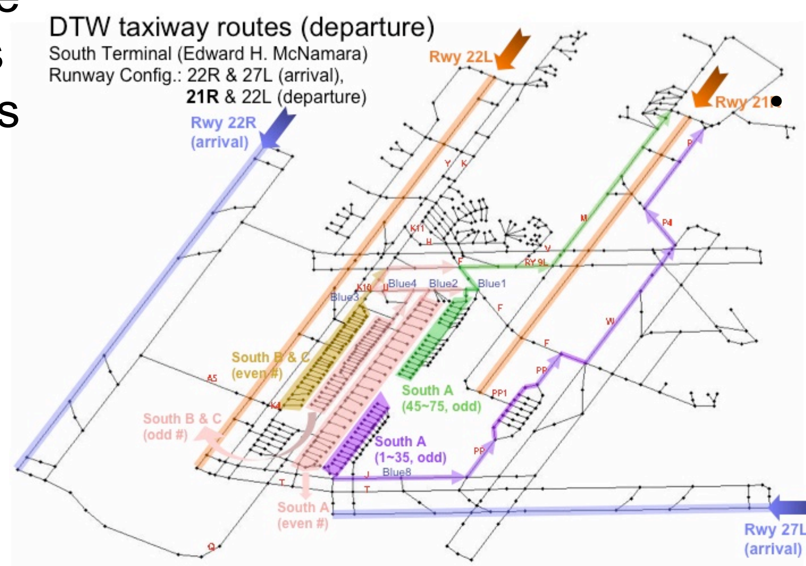
NextGen-Airspace Project
Research Focus Areas (continued)

- ***Cross-cutting elements to support the functional thrusts***
  - Accurate trajectory predictions that are interoperable with aircraft Flight Management System and trajectory generations using prediction uncertainty growth and propagation ***(Trajectory Prediction, Synthesis, and Uncertainty)***
  - System-level performance assessments (what is the collective impact?), study key interactions among TFM, DAC, SA, ASDO, and Airportal RFAs, and develop scenarios, metrics, models, algorithms, assumptions, interfaces, etc. ***(System-Level Design, Analysis and Simulation Tools)***

Research Examples

Optimized Trajectory-Based Surface Operations

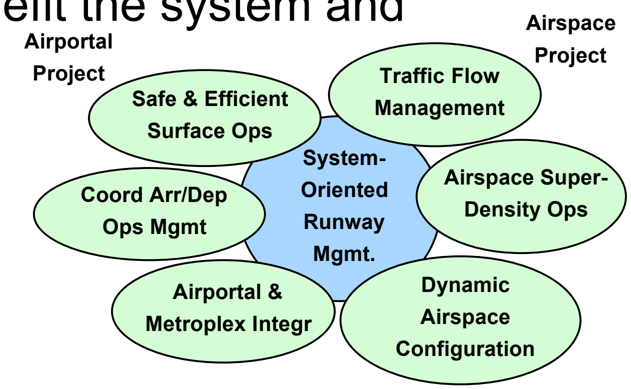
- Develop technologies to enable airport surface that:
  - Utilizes trajectories to control aircraft taxi operations
  - Optimizes pushback times and taxi routes to minimize engine-on time, taxi time/distance, and delays
  - Considers constraints (including environmental), uncertainties, stakeholder preference
  - Is highly coordinated with a runway scheduler to optimize the usage of airport resources
- Anticipated environmental benefits
  - Reduced fuel burn/emissions
    - Reduced engine-on time
    - Efficient taxi trajectories
    - Minimize/eliminate stops during taxi
  - Reduced noise



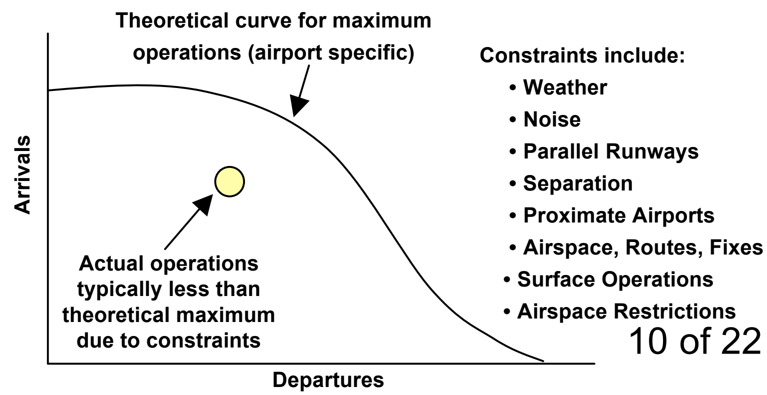
- Baseline Results
  - Avg. taxi time: 15.52 min.
- Results with gate holds assigned
  - Avg. taxi time from model: 11.95 min. (23% decrease)

System-Oriented Runway Management

- Runway Configuration Management (RCM)
  - Determines optimal configuration based on systemic traffic flow interests, proximate airport flow, weather, environmental constraints, availability of airport assets
- Combined Arrival/Departure Runway Scheduling (CADRS)
  - Optimizes runway usage, for defined runway configuration, that effectively coordinates arrival/departure operations to benefit the system and stakeholders



- Anticipated environmental benefits
  - Reduced emissions
    - Efficient airport reconfiguration - minimize excess taxi distance, arrival holds
  - Reduced noise
    - Runway configuration/usage accounts for local noise standards and constraints



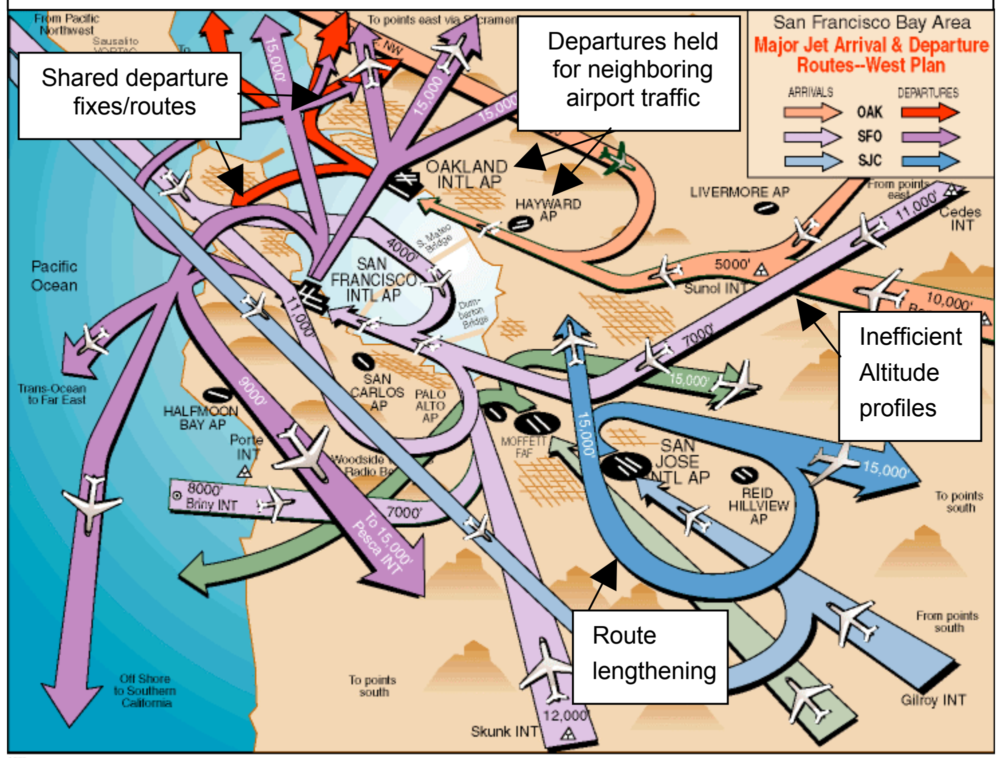
Metroplex Operations

- Metroplex: A group of two or more airports whose arrival and departure traffic is highly interdependent (JPDO definition)
- Typical metroplex interdependencies impacting environment in today's NAS:
  - Shared airspace, fixes, and routes: Slows or stops departures at one airport to accommodate arrival/departure traffic at another

- Mitigate metroplex interdependencies
  - Define operational concepts utilizing promising strategies
  - Validate concepts using fast-time and real-time human-in-the-loop simulations and field studies

- Anticipated environmental benefits
  - Reduced fuel burn/emissions
    - Minimum-distance routing
    - Efficient arrival/departure paths
    - Reduced departure delays
  - Reduced noise
    - Efficient arrival/departure paths

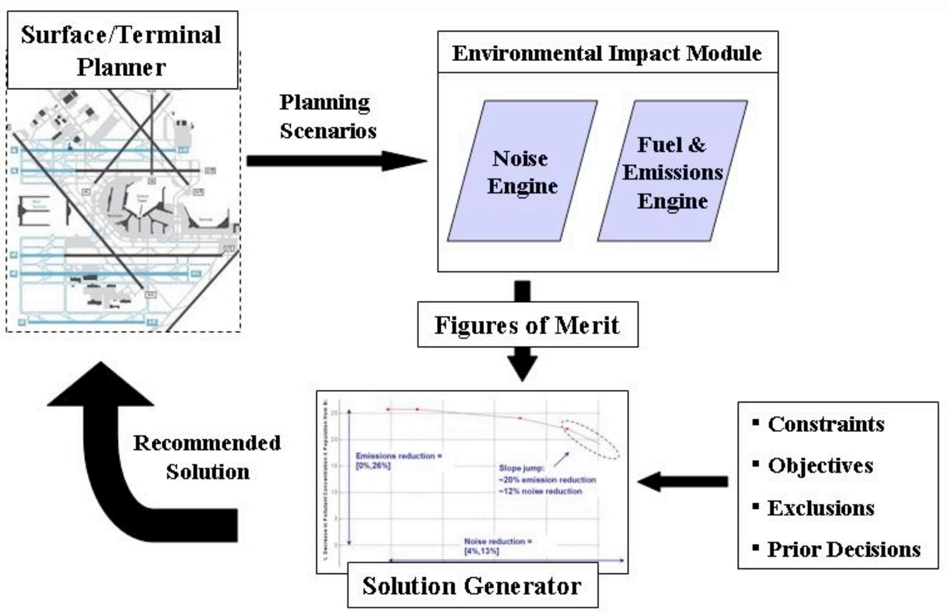
Typical technology-constrained metroplex interdependencies



Modeling Environmental Factors in Surface and Terminal Optimization (MEFISTO)

- Improvements in engines and airframes will help reduce emissions and noise at the source, but likely to be gradual and extend over a period of decades
- Focusing on the environmental constraints aspect of surface/terminal optimization, goals/constraints related to fuel, noise, and emissions may lead to a limited supply of “slots”

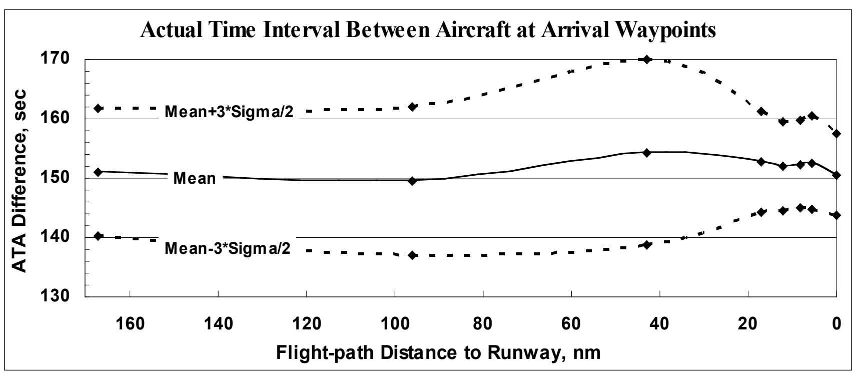
- Develop an Environmental Planner (EP) to:
  - Analyze noise/emissions
  - Advise a surface planner to mitigate critical noise and emissions issues
  - Integrate with a surface optimization algorithm to provide an environmentally sensitive optimized scheduling capability



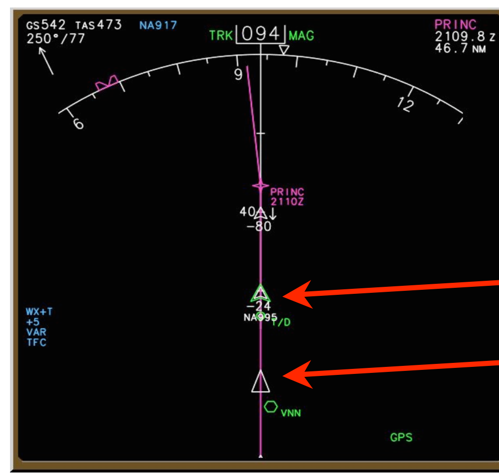
Specific Examples

CDAs with Merging and Spacing Technology

- Continuous Descent Arrivals (CDAs) is the goal
- Trade-off between CDAs and throughput
- Examined the flight deck merging and spacing technologies to increase throughput at the runway threshold while maintaining near-CDAs
  - A human-in-the-loop simulation was conducted using 26 pilots and 3 controllers
  - Flight crew followed on-board speed guidance to maintain controller assigned spacing using Airborne Spacing for Terminal Arrival Routes system
- Results indicated that higher runway threshold accuracy was maintained (error of only 0.8 sec) indicating that higher throughput can be maintained



Speed Guidance



Lead Aircraft

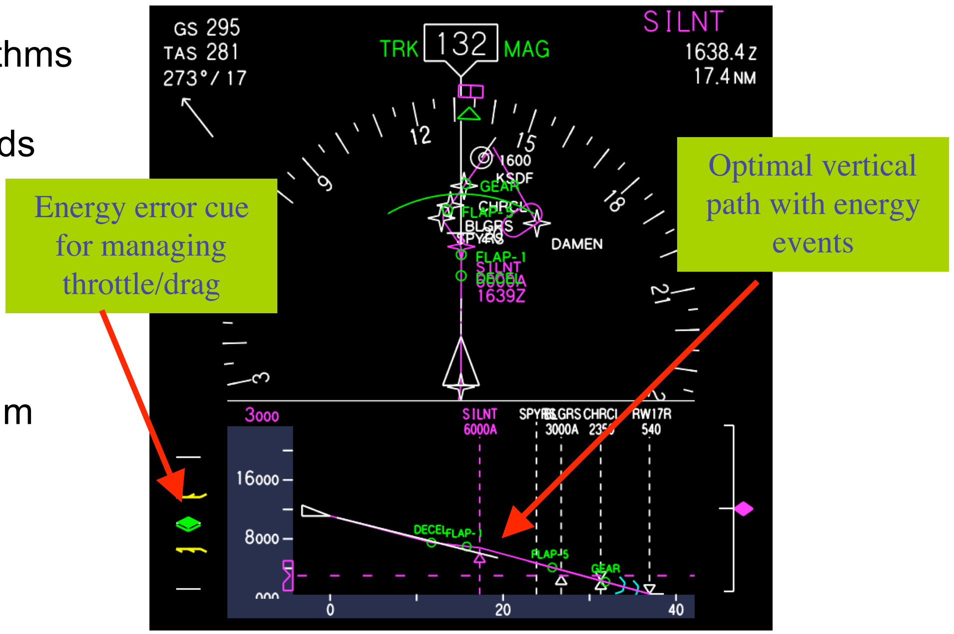
Ownship

NextGen-Airspace Project
Energy Navigation

Conduct simulations to identify the benefits of energy navigation concept and technology called energy Navigation (eNAV)

- Enabling research pursued in FY2009
    - Optimized vertical trajectory development algorithms that minimizes fuel, noise, and emissions
    - Dynamically recomputed to reflect changing winds
    - Flap/gear deployment timed to manage energy
    - Energy error guidance cue eliminates excessive throttle and speed brake usage

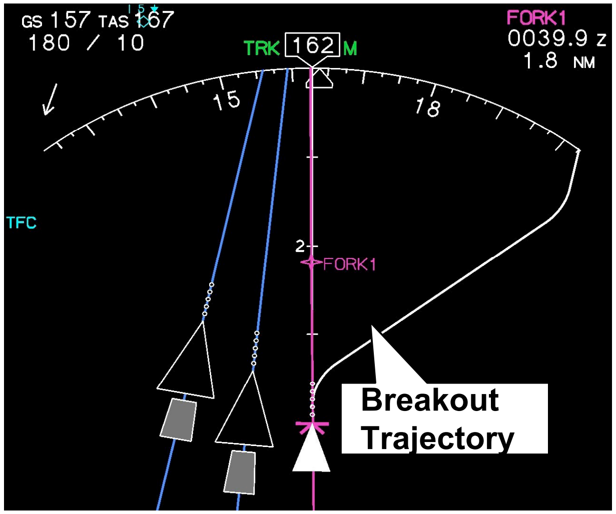
- Analysis and integration done in FY2010
    - Conduct non-piloted batch simulation of maximum capacity arrival rush with and without eNAV to determine benefits
    - Airborne Spacing for Terminal Arrival Routes algorithm used to achieve and maintain precise temporal spacing between aircraft from different flows to same runway
    - Systematic variations of wind uncertainty, traffic mix, and initial conditions
    - High fidelity models provide accurate fuel and noise metrics

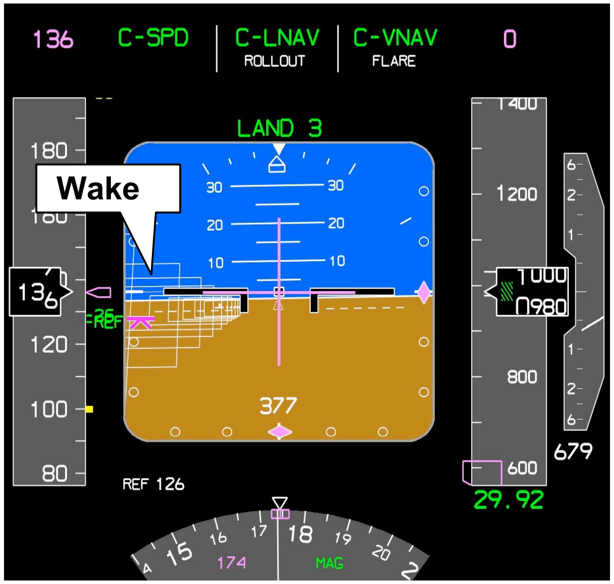


Navigation Display

Very Closely Spaced Parallel Approaches

- **Triple Very Closely Spaced Parallel Runway** Study was completed in August 2008
  - 8 pilots - 24 runs per pilot
  - DFW adapted for the study
  - Three aircraft echelon formation with the leader in the leftmost position
  - Navigation display showed 3 aircraft, predictor dots, wake location, breakout trajectory and a longitudinal situation indicator
  - Navigation display alerted for wake intrusion and aircraft blunder
  - Yellow alert indicated breakout might be imminent
  - Red alert indicated breakout was immediately necessary
  - Breakout trajectories were flown manually
- Variables studied
  - Cause for breakout (wake or aircraft deviation)
  - Location of breakout (above or below 500 feet)
  - Position of ownship (center or trailing)



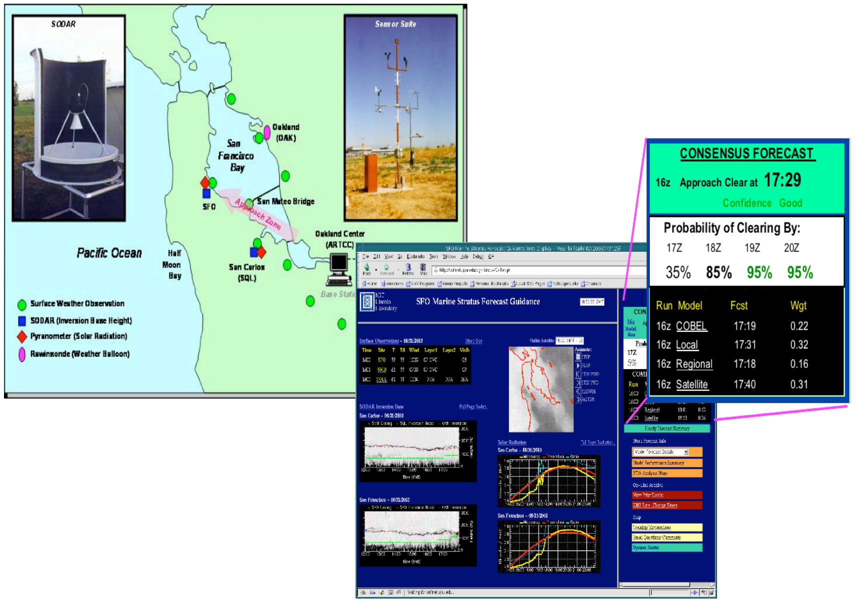


Results: The pilot participants successfully flew the simulator accurately and safely across all conditions

San Francisco Stratus and Flow Scheduling

- Develop decision support to <u>reduce delays</u> for San Francisco arrivals based on <u>better stratus forecast and flow management algorithms</u>

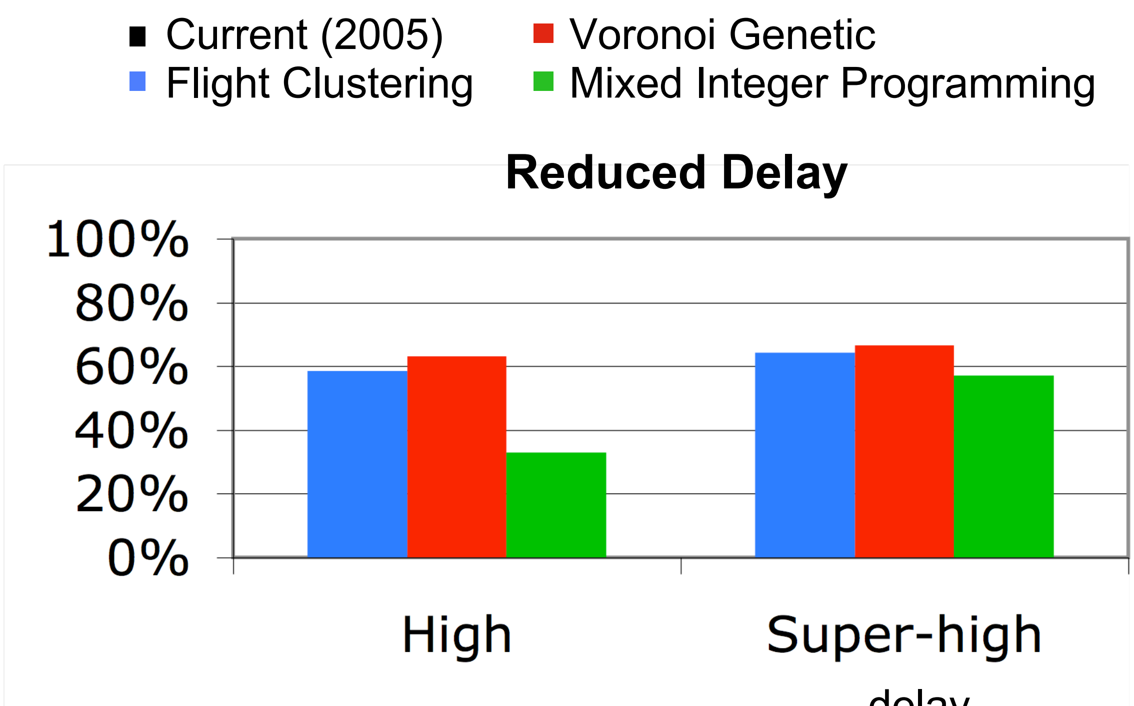
- Enabling research pursued in FY2009
  - Model developed to recommend key parameters for establishing Ground Delay Programs at SFO
  - Model uses probabilistic weather data from the National Weather Services' SFO Status Forecast System
  - Model leverages the FAA's operational ground delay program modeling system, and requires no modifications to the operational system
- Analysis and integration done in FY2010
  - Field evaluation of a model at the FAA Air Traffic System Command Center to enhance Ground Delay Program decision making with probabilistic stratus clearance time forecasts at San Francisco International airport
- Collaboration with FAA and NASA Research Announcement partner

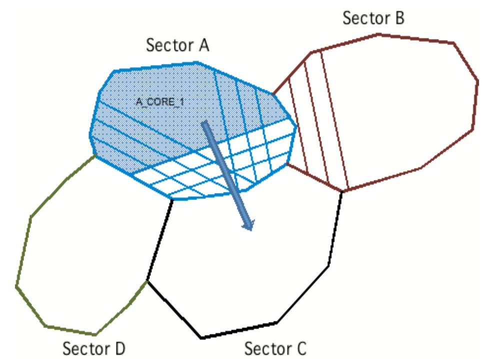


- Potential benefits
  - Model recommends Ground Delay Program end times that are on average 58 minutes earlier than operational times
  - **Estimated savings to airlines: $2.8 million/year**

Airspace Redesign Benefits

Comparison of single day NAS-wide sectorizations





Higher is Better

$$\text{Reduced Delay} = 1 - \frac{\varepsilon}{\varepsilon_0}$$

delay

current day sectorization

All 3 new sectorizations reduce delay over current day sectorization.

Tailored Arrivals

Estimated Fuel Savings

		Distance flown from CREAN to SFO (nmi)	Fuel Burn from CREAN to SFO (lbs)	Fuel Savings (lbs)
Tailored Arrivals		233	7,500*	
Baseline	Light	239	7,727	**227**
	Med	244	7,858	**358**
	Heavy	273	11,680	**3,219**

*For the heavy scenario, a fuel penalty of 961 lbs was added to the Tailored Arrival scenario. This delay was required to in order to match the arrival times at the meter fix (TRACON boundary) of both the Tailored Arrival flight and the Baseline flight, since both flights - under heavy traffic conditions - will be subject to the same TMA scheduling constraint. The fuel penalty was calculated by assuming the delay was absorbed in cruise (between CREAN and TOD) using a path-stretch maneuver.

Estimated Emissions Reduction

		Emissions from CREAN to SFO				
		CO (lbs)	NO_x (lbs)	C_xH_x (lbs)	CO_2 (lbs)	CO_2 Savings (lbs)
Tailored Arrivals		17.5	134.0	0.77	23,618	
Baseline	Light	19.1	135.6	0.82	24,333	**715**
	Med	19.3	138.1	0.84	24,746	**1,128**
	Heavy	19.7	238.6	0.95	36,782	**10,137**

Summary

- End goal is to increase capacity, efficiency, and throughput
- Program products are directly related to environmental considerations
  - Reduced emissions are result of reduced delays
  - Reduced emissions are result of efficient routes

Back Up Slides

Research Focus Area
Separation Assurance

Problem

- Human control of separation assurance limits the capacity of the airspace

Expected Impact or End Result

- Development of architectures, systems and algorithms to assure multi-aircraft separation and trajectory control

Research Being Pursued

- Efficient arrivals into capacity constrained airspace
- Airborne and ground-based separation assurance concepts and technologies
- Separation assurance and collision avoidance algorithm compatibility

Research Focus Area
Airspace Super Density Operations

Problem

– Human control of spacing and separation assurance limits the capacity of the terminal airspace

Expected Impact or End Result

– Concept of operations definition
– Development of multi-objective sequencing, merging and de-confliction algorithms
– Development of precision spacing and merging technologies
– Scalable technologies for regional and metroplex airport use (significant Airportal interaction)

Research Being Pursued

– Algorithms that solve/optimize simultaneously the sequencing, merging, de-confliction and spacing
– Regional resource utilization or metroplex operations
– Closely spaced parallel runways

Research Focus Area
Traffic Flow Management

Problem

– Planning involves multiple time scales (local, regional, and national)
– Multiple decision with different goals (pilots, dispatchers, ATSP flow managers)
– Decision making under uncertainty (e.g., weather)

Expected Impact or End Result

– Modeling, simulation and optimization techniques to minimize total system delay (or other performance functions) subject to airspace and airport capacity constraints while accommodating three times traffic in the presence of uncertainty

Research Being Pursued

– Optimization methods for advanced flow management
– Probabilistic and stochastic methods to address system uncertainties
– Weather Translation
– Collaborative Traffic Flow Management

Research Focus Area
Dynamic Airspace Configuration

Problem

- Limited degrees of freedom for airspace changes (e.g., combine two adjoining sectors)
- Substantial time to modify airspace (years) and train controllers (months)

Expected Impact or End Result

- Development of concepts, algorithms, and technologies that define airspace tailored to demand

Research Being Pursued

- Structure of the airspace (e.g., corridors-in-the-sky)
- Algorithms for airspace configurations - benefits and feasibility considerations
- Generic airspace

Research Focus Area
Trajectory Prediction, Synthesis and Uncertainty

Problem

- Lack of interoperability of trajectory prediction techniques
- Lack of functional specific requirement and standards

Expected Impact or End Result

- Development of ATC and Flight Deck Interoperable trajectories
- Trajectory prediction standards
- Trajectory uncertainty propagation

Research Being Pursued

- Trajectory predictions accuracy as a function of time, model parameters, meteorological effects and aircraft intent modeling
- Trajectory modeling requirement, analysis and validation

Research Focus Area System-Level Design, Analysis and Simulation Tools

Problem

- Complex and interacting concepts and technologies
- Collective impact of concepts and technologies is not easily understood

Expected Impact or End Result

- System level impact assessment
- Interactions between key research focus areas

Research Being Pursued

- Metrics, scenarios, assumptions, and models
- Interaction studies
- System-level performance assessment

System-Level Assessment I

- Objective
  - Provide system-level assessment of future concepts and technologies developed by the Research Focus Areas of the Airspace Systems Program for controlling and managing air traffic.
    - Experiment 1 objective is to assess the system-wide benefits of a set of integrated Next Generation (NextGen) future Concept Elements under varying traffic demands and a set of metrics and scenarios (Baseline 2006, NGIP 2018, NextGen 2025).
- Technical Accomplishments
  - Final draft of Experiment 1 near completion and under review.
  - Seven concept elements implementation plans have been developed. These plans are under review and include technical challenges, risk assessments, work requirements and implementation time.
  - Cluster analysis report has been completed. It provides 2006 baseline days with high and low traffic and five cluster days for annualization

Modeling Environmental Factors in Surface and Terminal Optimization (MEFISTO)

- As demand and environmental constraints increase, we face a problem in the allocation of limited resources
  - Improvements in engines and airframes will help reduce emissions and noise at the source, but likely to be gradual and extend over a period of decades
  - Focusing on the environmental constraints aspect of surface/terminal optimization, goals/constraints related to fuel, noise, and emissions may lead to a limited supply of "slots"

- Develop an Environmental Planner (EP) to:
  - Analyze noise/emissions output in near real-time for data from recent flights
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